The "In" in Inmos Stands for Innovation

By

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Inmos was a semiconductor company founded on certain principles of innovation:

- Hire smart, motivated engineers with purpose and give them the tools to achieve;
- Have a mission that matters and employees with a stake in the company's success;
- Embrace innovation and integration throughout the company;
- Invest in both breakthrough products and incremental technical improvements for immediate cash flow;
- Use technical leadership as a competitive advantage.

Its three founders, Richard Petritz, Iann Barron, and Paul Schroeder were all highly respected innovators in semiconductor technology, memories and microprocessors, and they applied those principles to foster the innovative spirit within the company. In five years, the company built three wafer fabrication facilities (a small R&D fab in Colorado Springs, CO, and two manufacturing facilities, one in Colorado Springs, CO and one in Newport, South Wales, England), and grew from zero to $150M USD in sales of leading-edge high-performance static and dynamic random access memories.

Advanced Manufacturing

Inmos was the first company in the world to use steppers for all photolithography operations in manufacturing, which allowed for smaller feature size, higher density, and better yield than other manufacturing approaches. Inmos was also the first to use 5x lenses for higher throughput in photolithography. Inmos implemented leading-edge ion implantation equipment and anisotropic plasma etch equipment to help reduce feature size and improve transistor characteristic. Inmos also drove yield through the innovative use of column redundancy in memory arrays which provided for replacement memory elements to enhance yield without affecting access time performance.

Microprocessor Innovation and Parallel Computing

Inmos was also the first company in the world to envision and realize a microprocessor system and computer programming language which supported inherent parallel processing. The processor was dubbed the <u>Trans</u>puter for being orthogonal to the conventional thinking of microprocessor architecture at the time, and potentially as disruptive to the industry as the transistor was to electronic switches; the programming language was called Occam, from the Occam's razor principle that "Entities should not be multiplied unnecessarily[1]."—in other words, keep it simple.

Award-winning Facilities

Innovation driven by the Inmos team was not limited to just semiconductor design and processing. Even the wafer fabrication facility in Newport, South Wales, won architectural awards for its innovative design:

- The Structural Steel Design Award 1982;
- Financial Times 'Architecture at Work' Award Commendation 1983;
- Eurostructpress Award 1983;
- Constructa Preis for Overall Excellence in the Field of Architecture 1986.

Having a suspension bridge-type structure for its roof, eliminated the need for interior supports and thus providing greater flexibility for arranging the wafer fabrication equipment within the room. This allowed for increased flexibility and optimization of the layout for production efficiency[2],[3].

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[1] http://www.merriam-webster.com/dictionary/occam%27s%20razor
[2] http://www.inmos.com/images/buildings/index.html
[3] http://www.richardrogers.co.uk/work/buildings/inmos_microprocessor_factory

Figure 1. The Inmos Wafer Fabrication Facility in Newport, South Wales

Invention and Intellectual Property

These and other revolutionary innovations in process technology, circuit design, manufacturing methods, and microprocessor architecture moved Inmos to the cutting edge of technology at the time. So how did Inmos compare with other companies in the innovation department? One measure of innovation is the number and quality of patents granted within the first years of a company's life. Compared to close peers of its time, Inmos proved to be 200% more innovative than the typical company in that era. The following charts (Figures 2-5) show the number of US-granted patents by priority year for the first 10 years of each company's life, starting from its founding year. The "priority year" is the earliest date to which a patent application can claim priority, i.e., when it can be proven that the invention was made. Usually, the priority date is the file date of the patent application. Selecting "peer" companies allows direct comparison of Inmos with other semiconductor startups in the "golden age" of semiconductors.

IP Productivity

The first two companies compared are Inmos and Micron. Both companies were founded the same year (1978), with the founders of both companies coming from Mostek. The eleventh year of Micron's patent history is included to illustrate that Micron finally woke up to the fact that patents are an important part of building value within a company. The second two companies compared are LSI Logic (founded in 1981) and Cypress Semiconductor (founded in 1982). Both were San Francisco Bay-area startups. LSI's focus was clearly on establishing a solid patent portfolio, while Cypress appeared to be more opportunistic in its approach to patents. Both companies have been successful in the market, longer term. Of these four companies, only LSI Logic was more prolific than Inmos at developing patentable technology in the first 10 years of its life.

Over its relatively short life, Inmos (as original assignee) was granted 136 US patents and a total of 517 patents (as families stemming from the original Inmos patents) worldwide. Figure 6 shows the distribution of Inmos patents by technology; as expected, the majority relate to semiconductor memory and microprocessor design. In 1989, the US patents were assigned to Thorn EMI North America, a patent licensing entity, which licensed the Inmos patents and generated an annual royalty stream of $69,200,000.[4] While detailed information is not publicly available, one source states that the value of the licensing royalties was at least $240M[5]. This royalty stream paid off Thorn EMI's investment in Inmos within a few years—providing a very handsome return on investment.

[4] http://www.manta.com/c/mmnt73k/thorn-emi-north-america-inc

[5] https://www.linkedin.com/in/johnskolas

A second measure of patent quality and innovation is the number of forward citations by other companies. As shown in Figures 7 and 8, the 517 Inmos patents have been cited 3,497 times—a strong indication that the Inmos innovations were pioneering, providing fundamental improvements to the technology related to memories and microprocessors. Figure 9 shows the distribution of the forward citations by technology area.

Inmos patents and technology were also the foundation of NMB Semiconductor, which was founded in 1984 by Takami Takahashi in Japan. The products initially fabricated in the $300M wafer fabrication facility in Tateyama, Japan, were based on Inmos patents, technology, and designs. The NMB facility was Japan's first start-up that was highly automated and capable of fabricating products with sub-micron geometries[6]. Inmos licensed its patents to NMB Semiconductor, and transferred the DRAM technology into production at the Tateyama facility. The NMB Semiconductor fab later became a foundry for Intel, Ramtron (another Inmos legacy company), United Memories[7], which was also founded by ex-Inmos employees, and National Semiconductor[8].

Lessons Learned

Inmos demonstrated that, by applying the principles of innovation outlined above, a company can stimulate innovation and create substantial value for shareholders. Inmos had its share of experienced prima donnas, but it was the young, talented engineers (who didn't know it couldn't be done) catalyzed by an environment that supported high-energy rapid innovation that made it happen. While a complex set of political and business circumstances beyond the control of Inmos management led to the absorption of the company and its people into the greater universe of semiconductors[9], the Inmos legacy of innovation impacted the global path of technical development in microelectronics, industry competition, useful new products, and a family of entrepreneurial companies, all spawned from the seeds of this highly innovative company.

[6] http://archive.computerhistory.org/resources/access/text/2013/04/102723194-05-01-acc.pdf, page 379
[7] http://www.chipsetc.com/nmbs---nmb-semiconductor.html
[8] http://www.joc.com/maritime-news/international-briefs_19860922.html
[9] http://www.inmos.com/inmos_legacy.html

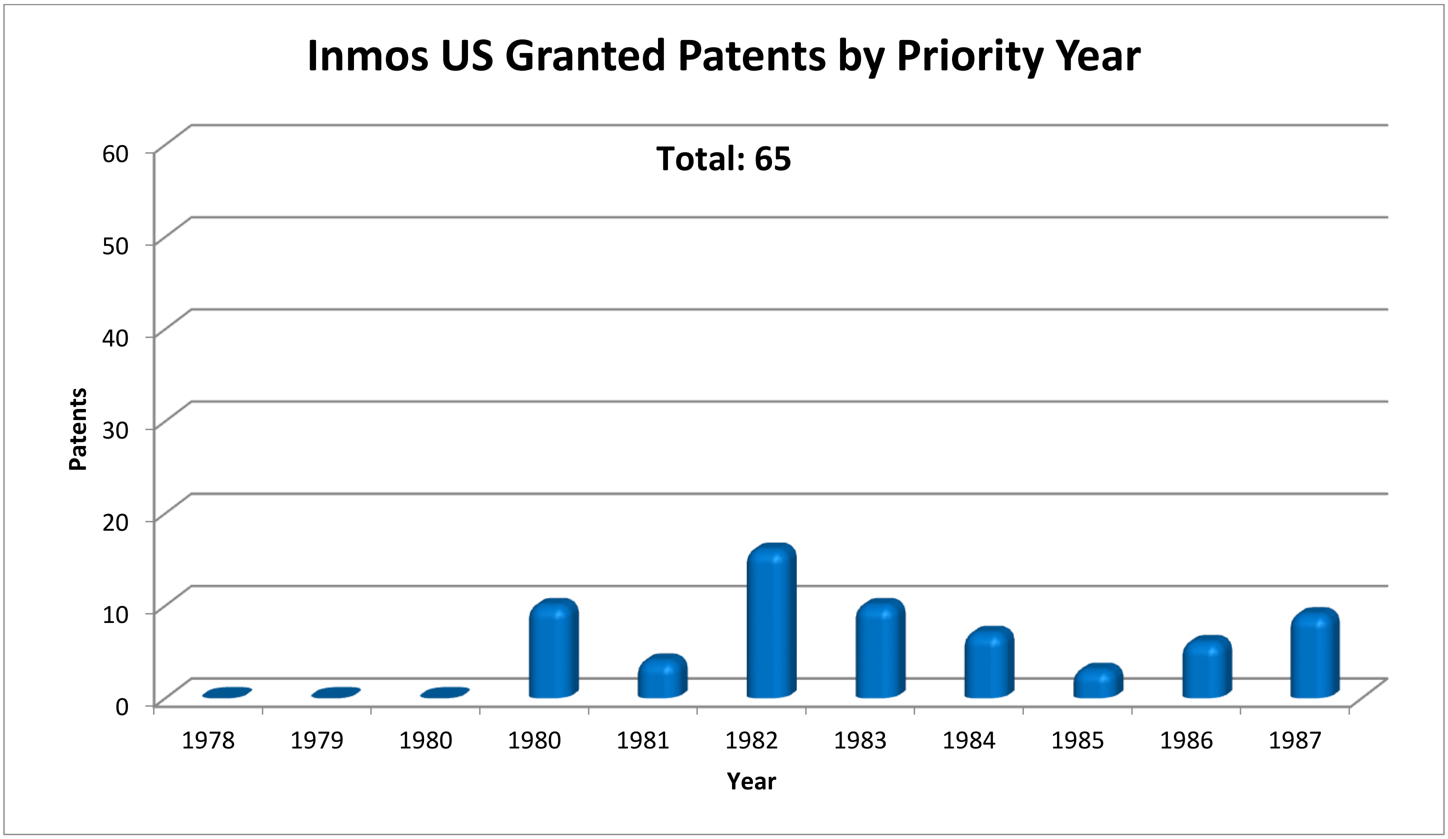

Figure 2. Inmos Patents by Priority Year: Founding year: 1978 (November)

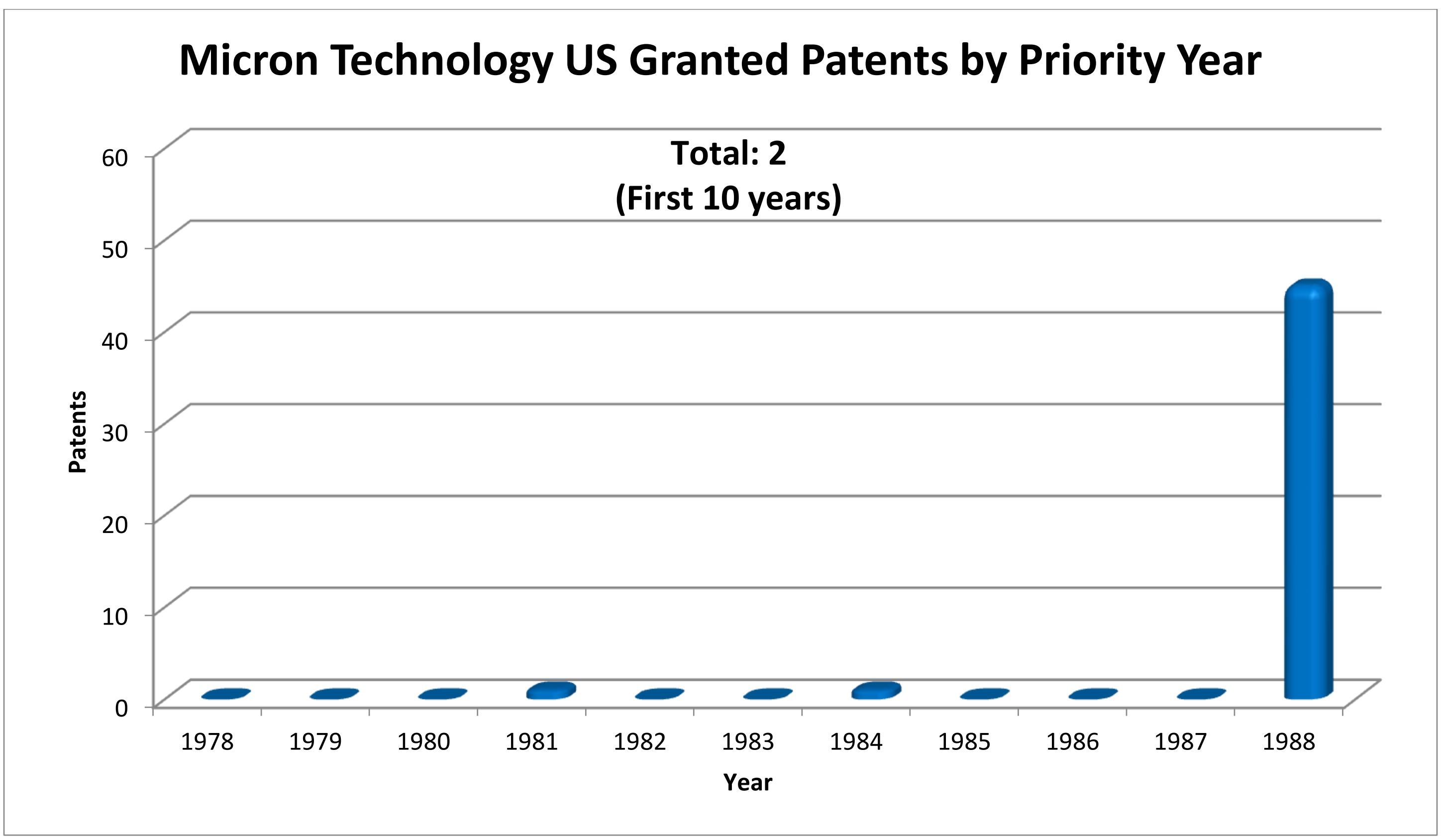

Figure 3. Micron Patents by Priority Year: Founding Year: 1978

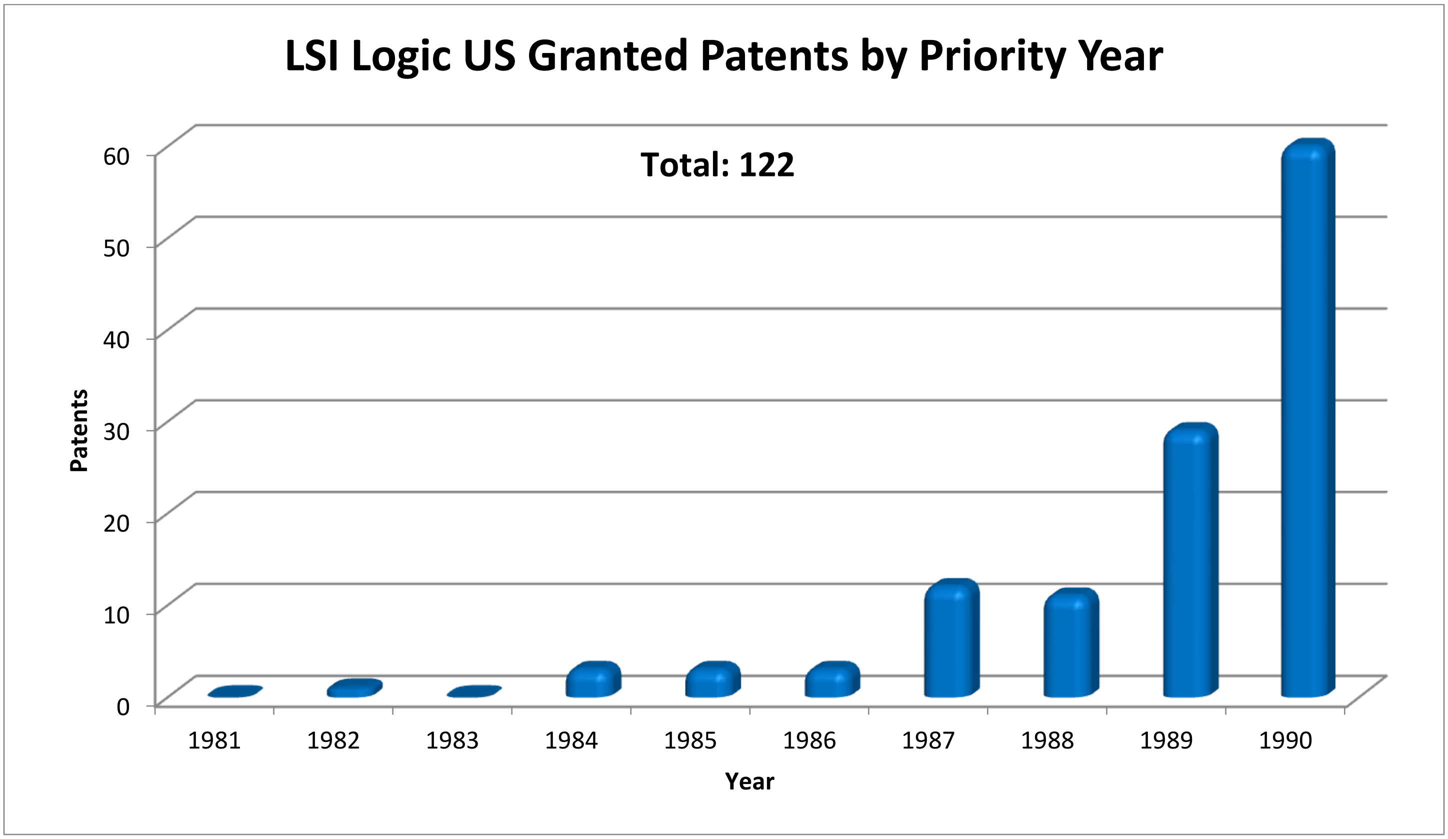

Figure 4. LSI Logic Patents by Priority Year: Founding Year: 1981

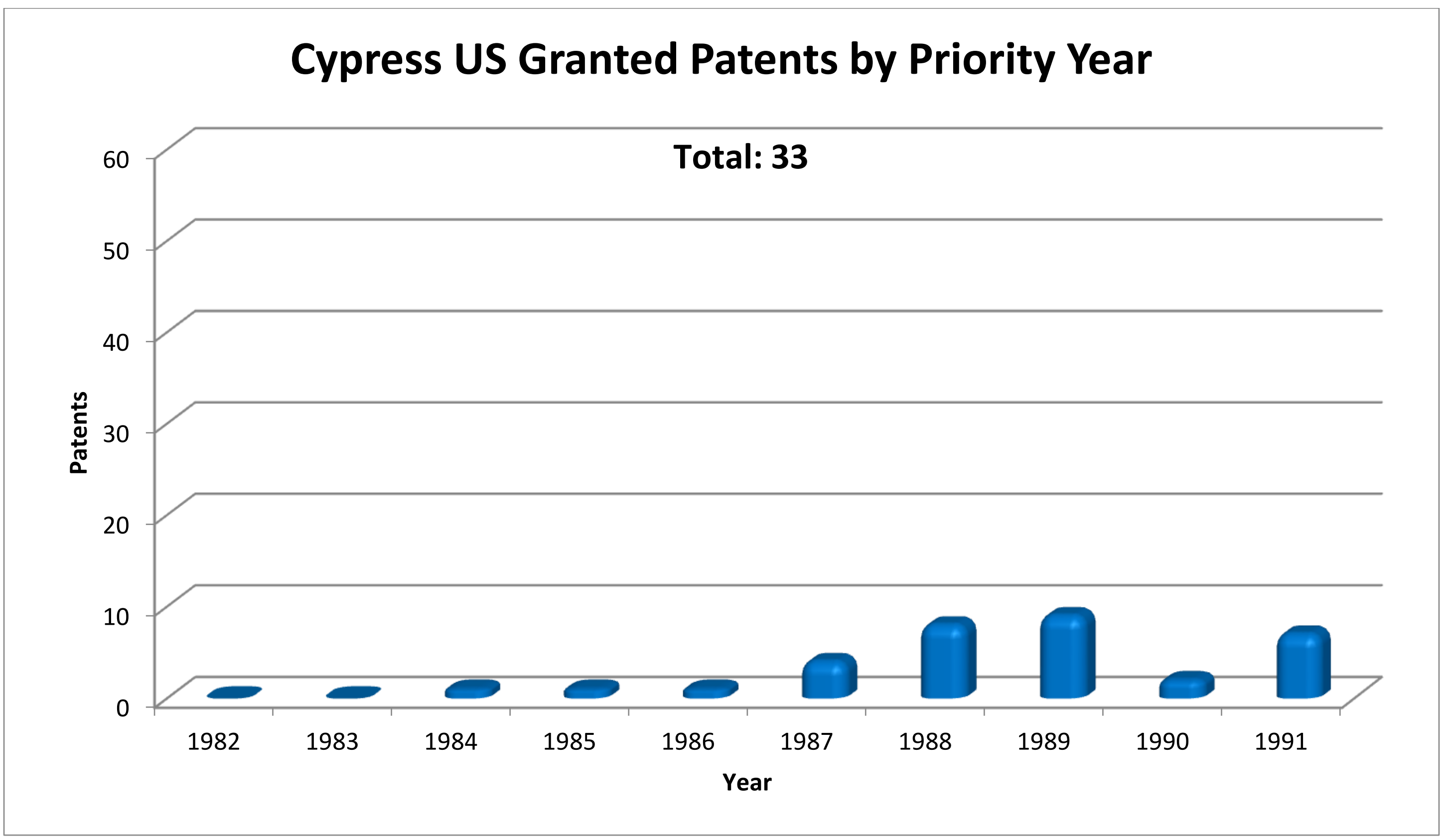

Figure 5. Cypress Patents by Priority Year: Founding Year: 1982

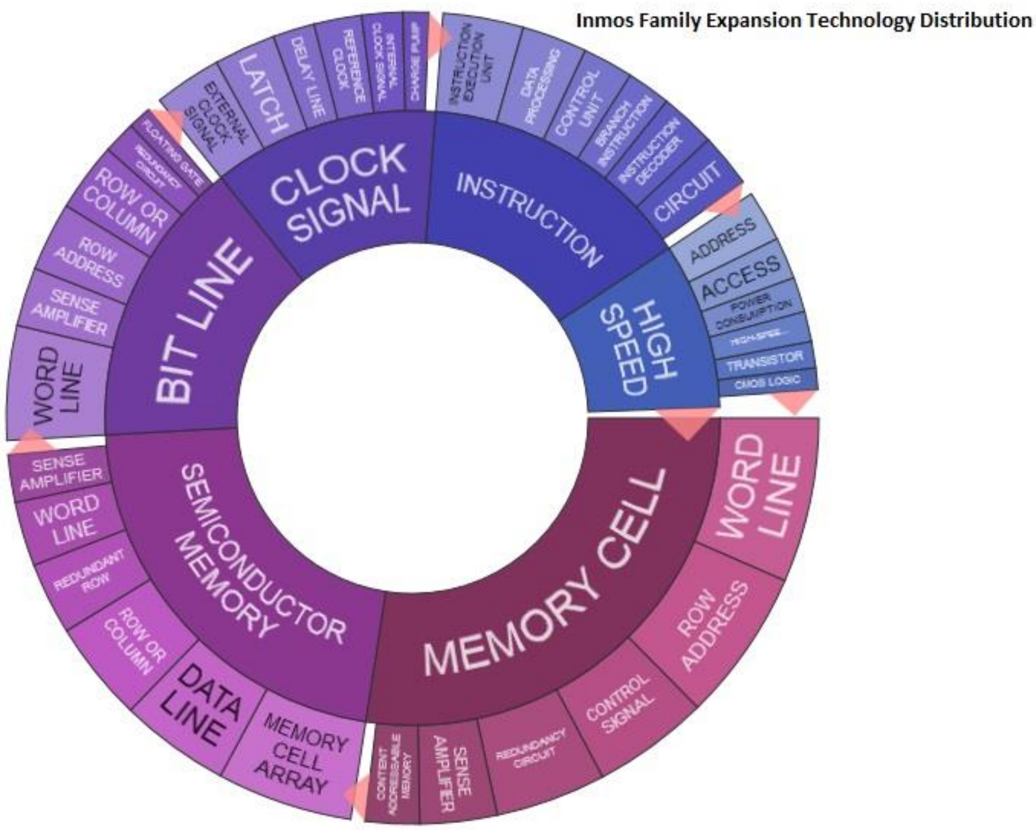

Figure 6. Inmos Family Expansion Technology Distribution

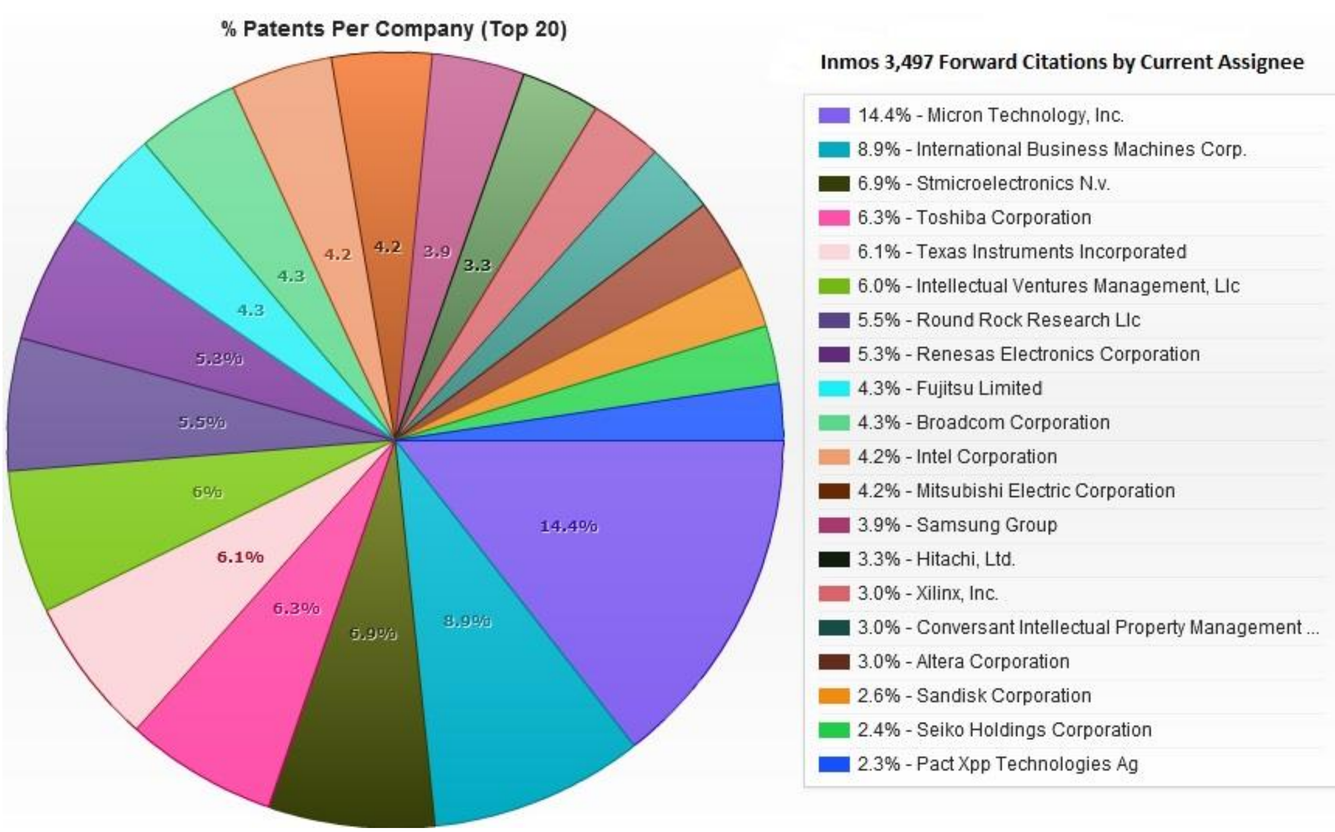

Figure 7. Inmos Family Expansion Forward Citations by Current Assignee

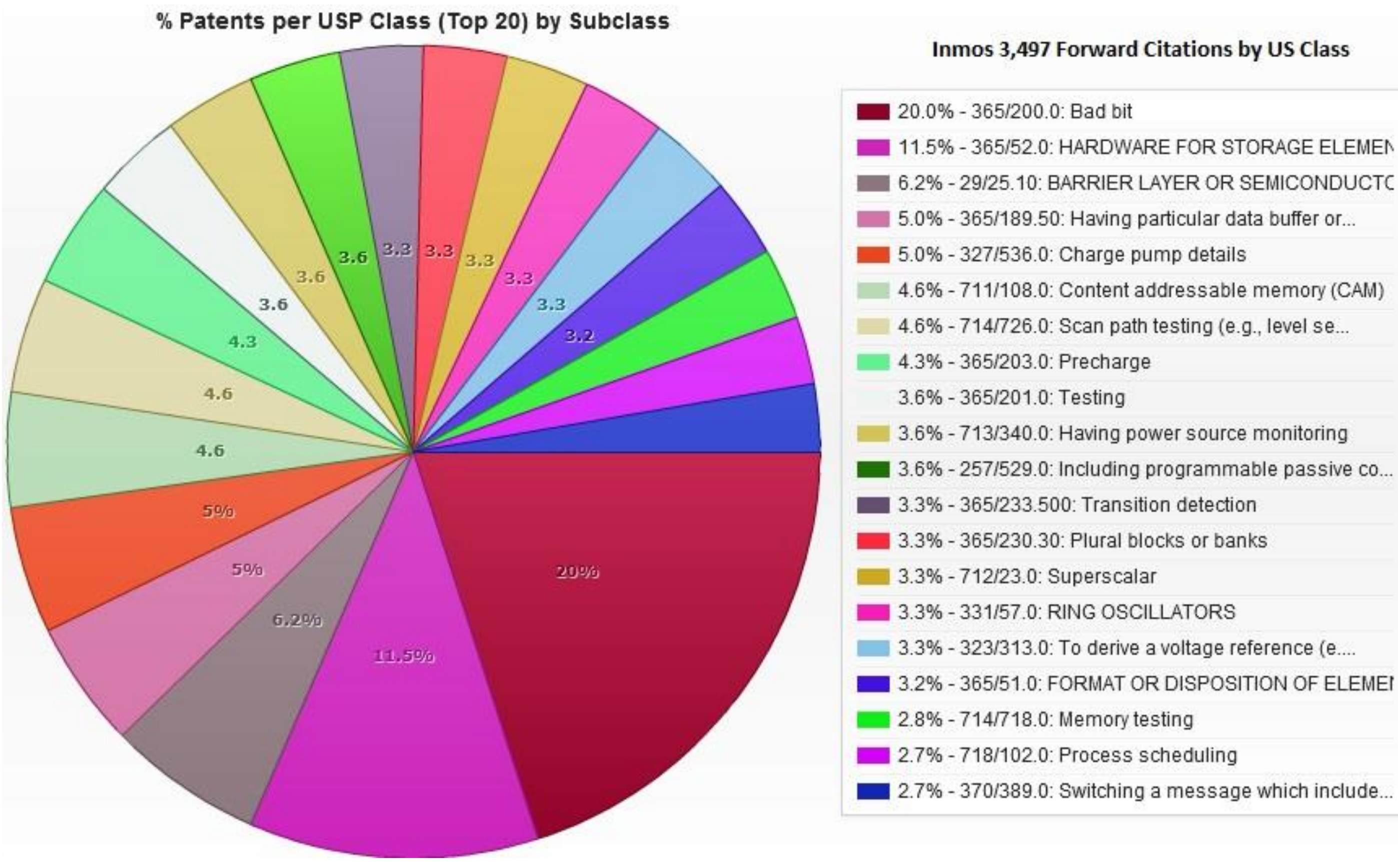

Figure 8. Inmos Forward Citations by US Class

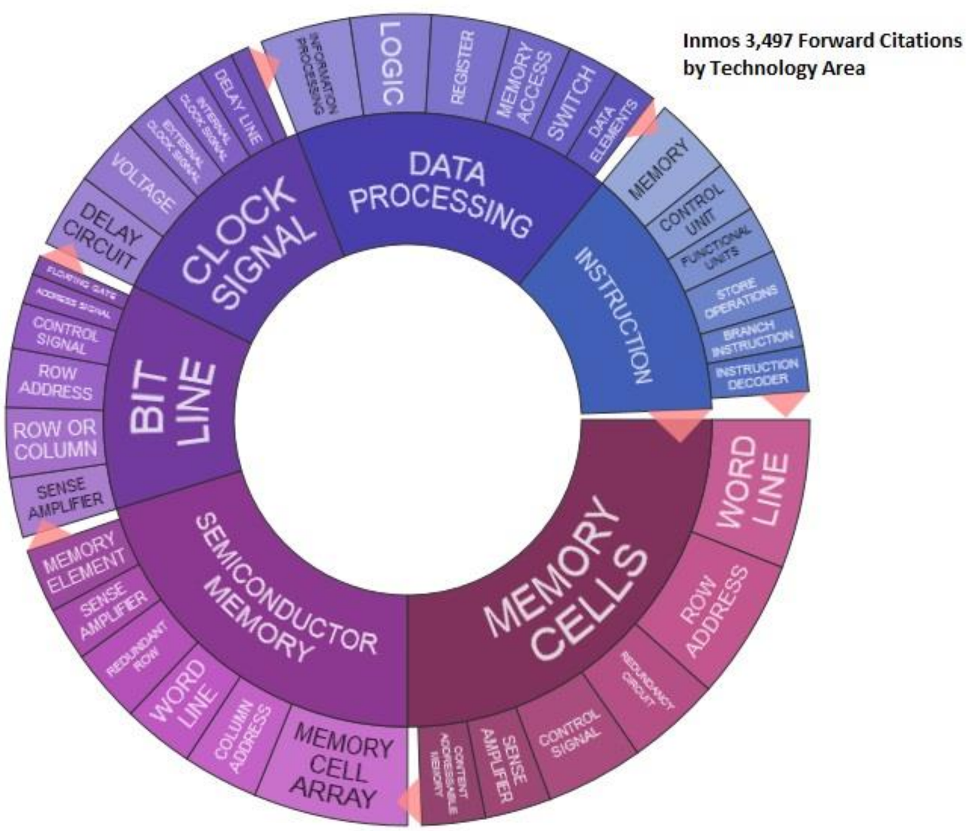

Figure 9. Inmos Forward Citations by Technology Area

Author's Biography

Dr. Adams joined Inmos in October of 1979 as employee number 47. He was initially responsible for the development of the process technology for Inmos' high-speed SRAMs, later taking over responsibility for all product technology development for SRAMs, DRAMs, and the Transputer. He then became Vice President of Quality and Reliability, before the restructuring of the company by Thorn EMI resulted in the elimination of many top-level positions in the US. Prior to Inmos, Dr. Adams was a member of the technical staff at Sandia National Laboratories for 10 years, and was a program manager for the development of radiation-hardened memories and microprocessors, in particular for the Jupiter Orbiter/Penetrator and Solar Polar missions for the Jet Propulsion Laboratories. Since Inmos, Dr. Adams worked for Monolithic Memories, United Technologies Microelectronics Center, and for 21 years as Vice President of Engineering and Chief Technology Officer for TAEUS Corporation, an intellectual property services company. Since leaving TAEUS, he has been providing consulting services through his company, Innovation Paradigms, LLC.